STATEMENT OF WORK

for

PHASE C/D/E DESIGN, DEVELOPMENT AND OPERATION

of the

GRAVITY RECOVERY AND CLIMATE EXPERIMENT (GRACE) MISSION

for the

UNIVERSITY OF TEXAS
CENTER FOR SPACE RESEARCH

(July 21, 1997)

1.0 INTRODUCTION

The GRACE Mission will produce a new model of the Earth's gravity field every 12 to 24 days with unprecedented accuracy for a period of five years. This measurement duration allows for the separation of the temporal and static gravity field components, providing both a high-accuracy static field and its time variations. The GRACE Mission will acquire the data for the gravity fields by flying two low altitude polar-orbiting satellites in a loosely controlled tandem formation. Variations in the Earth's gravity field will cause the distance between the two satellites to change. This variation will be measured with an effective precision of less than one micrometer/second in the line-of-sight range rate by a microwave link between the two satellites. Analysis of the data from GRACE will result in numerous advances in Earth sciences related to oceanography, hydrology, glaciology, atmospheric sciences and the solid Earth sciences.

In July 1996, the Office of Mission to Planet Earth (OMTPE) at NASA Headquarters released the first Announcement of Opportunity for the Earth System Science Pathfinder (ESSP) Program. The ESSP Program is intended to accomplish high quality, focused Earth System Science measurements utilizing innovative, streamlined management and implementation approaches designed to yield high value science. The GRACE Mission proposal was selected after a rigorous, two-phased selection process.

The GRACE Mission is a team effort being led by Dr. Byron Tapley of the University of Texas Center for Space Research (UTCSR). The Co-Principal Investigator is Dr. Christoph Reigber of the GeoForschungsZentrum (GFZ). The GRACE Mission Team consists of UTCSR, the Jet Propulsion Laboratory (JPL), Space Systems Loral (SS/L), NASA Langley Research Center (LaRC), Dornier SatellitenSysteme (DSS) and, under an International Memorandum of Understanding between NASA and DARA, the GeoForschungsZentrum (GFZ), and the Deutsche Forschungsanstalt fur Luft und Raumfahrt (DLR).

This Statement of Work (SOW) defines the work to be performed during Phases C/D/E to design, develop and qualify the flight and ground segments for the Gravity Recovery and Climate Experiment (GRACE) mission, to plan for and execute the science operations, mission operations, data acquisition and distribution, and to operate the mission.

2.0 PROGRAM MANAGEMENT

The ESSP missions are to be implemented under a "Principal Investigator Mode" (PI Mode) in order to reduce mission development times, costs and schedules and achieve NASA goals within the current budget constraints. In the PI Mode, the PI takes full responsibility for all aspects of the mission, including instrument and spacecraft definition, development, integration, and test; ground system operations, science operations, mission operations, and data acquisition and distribution with the intention of allowing the PI the maximum flexibility to conduct the investigation. The PI will establish and lead a mission team, optimizing the specialized talents of the various participating organizations. The PI will have the responsibility and accountability to accomplish the mission within the program's cost and schedule constraints. The mission team will use their own processes, procedures and methods to the fullest extent practical, and also develop new ways of doing business where cost, schedule and technical improvements can be achieved. Periodic progress reporting will combine cost, schedule and technical status using the team's own internal management reviews to meet the Government's reporting requirements. The PI will submit an annual cost and obligation plan and submit monthly reports of actual costs and obligations. If either the PI or NASA determines that the mission cannot be completed within the agreed upon constraints, a termination review will be held. In the ESSP Program, the PI is accountable to NASA for Mission success and will be given full responsibility for all aspects of the Mission.

NASA HQ Code IY will provide support in the development of a Memorandum of Understanding (MOU) with international partners on the GRACE Mission. For all other aspects of the GRACE mission, NASA HQ has delegated program management responsibility for the GRACE mission to the ESSP Project Office at the Goddard Space Flight Center (GSFC). The GSFC ESSP Project Office will provide mission funding, contract administration and oversight for the GRACE Mission. To implement the GRACE mission, GSFC ESSP Project Office will provide funds directly to three members of the GRACE team - UTCSR, JPL and LaRC. Furthermore, the Project Office may provide mission unique support, only as may be requested by the PI in writing and agreed upon by the ESSP Project Manager. This support may be in the form of support personnel, equipment, parts/supplies, or facilities from NASA or other Government sources. To fund this support, a portion of the PI's Mission funds would be retained by the ESSP Project Resources Office, to be disbursed as directed by the PI.

The PI, Dr. Byron Tapley and the University of Texas Center for Space Research (UTCSR), shall take full responsibility for all aspects of the GRACE Mission from definition through mission operations and data distribution. It is understood for mission requirements outside the scope of NAS5-97213, the PI may effect changes through recommendations to the GSFC Mission Manager. The GRACE mission shall meet the

requirements contained within the Gravity Recovery and Climate Experiment Mission Definition and Requirements Agreement (MDRA) [Contract Attachment D] and be consistent with the design, development and operations plan as presented in the GRACE Proposal dated December 10, 1996.

JPL will be funded directly from the ESSP Project Office, and will receive technical guidance from Dr. Tapley for the GRACE mission. Specifically, technical direction by the GSFC ESSP Project Office will be provided to JPL in consultation with Dr. Byron Tapley of UTCSR. As defined in the International MOU being negotiated between NASA and DARA, German Mission Team members are under the direction of Prof. Christoph Reigber, with Dr. Byron Tapley maintaining overall responsibility for their performance as well.

The NASA LaRC will be funded directly from the ESSP Project Office, and will receive technical guidance from JPL and UTCSR for the GRACE mission. The GSFC ESSP Project Office will technical direction to LaRC in consultation with JPL and UTCSR.

3.0 SCOPE

During Phase C/D/E, UTCSR, together with the Jet Propulsion Laboratory (JPL) and the other GRACE Mission Team members shall provide the facilities, materials, services and personnel necessary to:

- design and develop flight qualified instruments which will perform the necessary scientific measurements to meet the objectives of the GRACE Mission;
- design and develop flight qualified spacecrafts and flight adapter for the GRACE Mission;
- integrate the instruments and spacecrafts together and test the resultant GRACE satellites;
- deliver flight qualified GRACE satellites for launch and support the launch operations;
- design and develop the ground system and control center for science and mission operations;
- operate the GRACE satellites on orbit; and

- acquire, calibrate, validate and deliver GRACE science data.

The design, development and operation of the GRACE Mission shall be based upon and be consistent with the design, development and operation plan as presented at the Mission Design and Cost Review (MDCR).

4.0 TASKS

In Phase C/D/E, UTCSR with JPL and the GRACE Mission Team shall provide the facilities, materials, services, and personnel necessary to implement the GRACE mission, and to achieve its scientific objectives. UTCSR shall provide sufficient oversight to JPL to allow them to lead the joint effort to design, develop, integrate and qualify for spaceflight, the two GRACE satellites and their instrumentation, and to insure compatibility of the flight segment of the mission with the launch vehicle and the Mission Operations Team. The tasks designated in this SOW are delineated in accordance with the GRACE Mission Work Breakdown Structure (WBS) provided in Attachment G of the contract. This WBS provides the basis for identifying, planning, budgeting, scheduling, controlling and reporting all effort on the contract.

4.1 PROJECT MANAGEMENT

UTCSR has delegated Project Management responsibilities to JPL. UTCSR shall therefore provide sufficient oversight for JPL to establish, implement and maintain a management system which integrates management disciplines (scientific and technical), functions, and systems into an overall activity to achieve cost-effective planning, organizing, controlling, and reporting of the contract objectives. The day-to-day management and administration of the specified work are the prime objectives of this task. As part of this effort, UTCSR and JPL shall provide traceability of cost, schedule and technical progress data for work being performed by Mission Team members and subcontractors in support of this contract. UTCSR shall coordinate with the Co-PI leading the international Mission Team to provide schedule and technical progress data for efforts being performed by those Mission Team members, including delivery of the launch vehicle and spacecraft bus, as well as preparations for spacecraft/launch vehicle integration, launch operations, flight operations and science data processing and delivery. All work performed by international GRACE Mission Team members shall be in accordance with established IMOU’s and contracts.

4.1.1 Schedules

UTCSR shall provide sufficient oversight for JPL to establish, implement and maintain a scheduling management function which develops, monitors and maintains the master schedule and derivative detailed schedules for the GRACE Mission development activities. These schedules shall establish the interrelationships and time-phasing of activities and events essential for the timely and effective implementation of the program, and shall identify critical paths and schedule slack. The initial master or level 1 schedule developed by UTCSR and JPL shall constitute the "baseline" schedule and shall come under configuration control consistent with the program configuration management procedures.

4.1.2 Monthly Progress Reports

UTCSR shall submit and present Monthly Progress Reports utilizing narrative text, graphs and/or schedules. Technical and schedule status of international Mission Team members shall be addressed. These reports shall include but not necessarily be limited to:

1) Summary Status - Summarize the current contract and schedule status. Identify any anticipated changes in scheduled milestones. Provide current status of all critical path items and report schedule slack. Provide current status of all mission critical technical resources (mass, power, etc.), including margins or reserves. Provide current status of mission cost reserves, including liens.

2) Major Accomplishments - Summarize achieved accomplishments versus planned accomplishments for the previous month and delineate planned accomplishments for the next month.

3) Current Problems - Present a “Top Ten” list of problems. State progress toward solving problems previously identified and discuss new problems that have been identified during the past month, including the schedule for resolution. State whether action by, or assistance from, either Mission Team Management or GSFC is required. Identify potential work around positions if a problem will have a significant impact on the on-time completion of the contract or on critical scheduled milestones.

4) Problem Avoidance - Recommend action by either Mission Team Management or GSFC which would assist in preventing major potential problems from developing.

5) Risk Management Status Report - Update the list of the high risk items, discussing any risk mitigation actions which were implemented and giving a status of upcoming risk decision points.

6) Performance Metrics Status Report - Give a status of the mission against the negotiated cost, schedule and technical performance metrics.

7) Facility Status Report - Discuss the status of facilities.

The Monthly Progress Report shall be submitted both electronically via e-mail and as three (3) hard copies to the ESSP Project Office at GSFC, with an accompanying teleconference or presentation. The location of any monthly presentations shall be determined by mutual agreement of the ESSP Project Office, UTCSR and JPL.

JPL, together with UTCSR shall conduct Quarterly Status Reviews with the ESSP Project Office. These reviews shall include up to date information on technical, cost, schedule and other programmatic issues. These reviews shall be conducted in person at either the ESSP Project Office or at a GRACE Mission Team member's facility, as agreed upon by the ESSP Project Office, UTCSR and JPL.

4.1.3 Monthly and Quarterly Contractor Financial Management Reports (533M/533Q)

UTCSR shall submit monthly and quarterly 533M and 533Q financial management reports or equivalent, as described in NPG 9501.2B "NASA Contractor Financial Management Reporting" (April 1996). GRACE financial management reports shall be prepared according to the WBS of Attachment H of this contract, or as agreed upon by UTCSR, JPL and the ESSP Project Office. Financial management reporting shall be provided at the total cost/manpower level for WBS Level III and by cost element for WBS Level II. 533M and 533Q reporting shall be required for first-tier subcontracts that meet the reporting requirements set forth in NASA FAR Supplement Section 18-42.7201 (b) (1). UTCSR and JPL shall also provide contract funding profiles, as required, and explain variances between projected and actual costs that are reported on 533M and 533Q reports.

4.1.4 Reviews

UTCSR, together with JPL shall provide the necessary resources to prepare technical and programmatic data packages for distribution and presentation at the following formal reviews, to be conducted by a JPL/GSFC appointed Review Panel:

1) Critical Design Review (CDR)

2) Test Readiness Review (TRR)

3) Pre-Shipment Review (PSR)

4) Launch Readiness Review (LRR)

The Review Panel will be co-chaired by a JPL-appointed Co-Chair and a GSFC-appointed Co-Chair. Advance copies of the presentation package shall be submitted to the ESSP Project Office for review at least 10 working days prior to the formal presentation.

UTCSR, together with JPL shall also conduct informal internal reviews, and shall establish a review team responsible for conducting the reviews and evaluating the status of the program. The team shall be comprised of individuals who have extensive experience with spaceflight programs and are independent of the GRACE Program. Examples of internal reviews are as follows:

1) Final Design Review (FDR)

2) Ground System Review (GSR)

3) Instrument Calibration Review (ICR)

4) Instrument Delivery Review (IDR)

5) On-orbit/Launch + 30 Days Review (OOR)

The ESSP Project Office will conduct a formal programmatic evaluation of the GRACE mission on a yearly basis, tied to a formal technical review or Quarterly Review, where possible. The result of this evaluation will be a recommendation to continue, descope or terminate the mission. The ESSP Project Office shall be invited to attend all reviews (both formal and informal) conducted by the GRACE Mission Team.

4.1.5 Meetings

The ESSP Project Office shall be invited to attend all meetings conducted by the GRACE Mission Team.

4.1.6 Risk Management

UTCSR, together with JPL, shall implement and maintain a Risk Management System which enables the mission team to minimize the schedule, cost and technical risks while remaining within the resource and programmatic constraints of the mission. As part of risk management, UTCSR, together with JPL, shall identify status, schedule, cost and technical risk areas of the GRACE Mission and implement necessary mission descopes in accordance with the GRACE Descope Plan section of the GRACE Phase C/D/E Project Implementation Plan.

4.1.7 Configuration Management

UTCSR, together with JPL, shall establish, implement and maintain a configuration management (CM) system for the GRACE Mission. The CM system shall apply to all work performed by UTCSR and its subcontractors, team members and suppliers. As a minimum, the CM system shall contain the following elements:

1) Identification of configured items which will be baselined and maintained under configuration control;

2) Description of how the various classification of changes will be handled, including how changes are recorded and reported;

3) Identification of a Configuration Control Board (CCB); and,

4) Verification of compliance with specifications and contract requirements.

UTCSR shall ensure that all documentation and drawings which come under CM control shall be retained for a period of not less than five (5) years after the completion of this contract.

4.1.8 Final Report

UTCSR, together with JPL, shall provide a Final Report that documents and summarizes the results of the entire contract work including recommendations, conclusions and lessons learned, based on the experience and results obtained in performing this effort. The Final Report shall be of sufficient detail to comprehensively explain the results achieved under the contract.

4.1.9 Science Management

UTCSR shall be responsible for providing scientific oversight for the GRACE Mission and the development of the instruments. UTCSR shall also provide scientific oversight for the development of GRACE science data processing algorithms and software, including post-launch science data acquisition and distribution.

UTCSR, together with JPL and the mission team members, shall define and develop the GRACE Project Data Management Plan (PDMP). The PDMP will describe policies and guidelines for the management, acquisition, processing, archiving and distribution of the GRACE science data.

4.2 SYSTEMS ENGINEERING

UTCSR shall provide sufficient oversight for JPL to establish a systems engineering capability which shall be responsible for integrating the technical efforts of the entire GRACE development team to ensure that the performance objectives of the Mission are met with minimum risk. In addition, UTCSR with JPL shall:

- provide mission requirements traceability consistent with the GRACE Science and Mission Requirements Document [contract Attachment D];
- perform trade studies and status assessments to support the management decision making process;
- support the risk management process by identifying and characterizing risks and developing appropriate risk mitigation approaches;
- ensure the compatibility of all functional and physical interfaces, both internal and external to the Instruments and Spacecraft, and verify that their designs reflect the requirements for all GRACE systems elements (hardware, software, facilities, personnel and data);
- ensure the compatibility of all functional and physical interfaces for the ground system, including the GRACE Control Center and PODAAC;
- ensure the compatibility of all functional and physical interfaces between the Instruments, Spacecrafts and/or Satellites and the ground support equipment (GSE);

- ensure the compatibility of all functional and physical interfaces between the Instruments, Spacecrafts and/or Satellites and the launch vehicle; and

- be responsible for all necessary systems level engineering activities associated with specialty disciplines which include, but are not limited to, reliability, contamination control, electromagnetic interference, space charging, and radiation effects.

4.3 PERFORMANCE ASSURANCE

4.3.1 Mission Assurance Plan

UTCSR shall provide sufficient oversight for JPL to establish, implement and maintain a performance assurance program for both hardware and software development that meets the requirements of the Mission Assurance Plan for the Gravity Recovery and Climate Experiment Mission. The performance assurance program shall apply to all work performed by JPL, its U.S. subcontractors and suppliers, and its U.S. team members. Effective management, control and implementation of the quality function is the prime objective of this task.

4.3.2 Safety Plan

UTCSR shall provide sufficient oversight for JPL to establish, implement and maintain a system safety program that meets the requirements of the Safety Plan for the Gravity Recovery and Climate Experiment Mission and accomplishes the following:

1) Identifies and controls hazards to personnel, facilities, support equipment, and the flight system during all stages of mission development. The program shall address hazards in the flight hardware, associated software, ground support equipment, and support facilities.

2) Meets the system safety requirements stated in any applicable launch site safety regulations. This shall include the development and submittal of any required safety data package, safety noncompliance requests, ground operations procedures, and payload organization launch site safety plan.

3) Meets the baseline industrial safety requirements of the institution, as well as any special contractually imposed mission unique obligations.

The safety program shall apply to all work performed by JPL, its subcontractors and suppliers, and Mission Team members.

4.4 FLIGHT SEGMENT

UTCSR, together with JPL and its Mission Team, shall provide the facilities, materials, equipment, services and personnel to integrate the GRACE instruments with the spacecrafts, perform subsequent satellite level tests and verification, and deliver two flight qualified GRACE satellites to the launch site. Specific activities include, but are not limited to: delivery of the instruments and spacecrafts to the satellite integration facility; electrical and mechanical integration of the satellites; end-to-end tests; comprehensive performance tests; preparation for environmental tests; electromagnetic compatibility tests; vibro-acoustic tests; network compatibility tests; thermal vacuum/ thermal balance tests; pre-environmental and pre-ship reviews; and shipment to the launch site.

4.4.1 International Coordination and Integration

UTCSR, together with JPL, shall be responsible for coordination delivery and integration of all necessary hardware and software components from international GRACE Mission Team members to U.S.-built hardware and software components, as well as shipping integrated hardware/software systems back to international Mission Team members for launch vehicle integration and launch.

4.4.2 Spacecraft

UTCSR, together with JPL and its Mission Team shall provide the facilities, parts, materials, services and personnel to design, fabricate, assemble, test and deliver for integration with the Instruments two spaceflight qualified Spacecrafts and a launch adapter for the GRACE Mission. These efforts shall include, but not be limited to, performing the necessary analyses to ensure functional requirements are met, and preparing design drawings and data packages. UTCSR and its Mission Team shall also develop any test equipment necessary to test the GRACE satellites.

UTCSR, together with JPL and its Mission Team shall also provide the facilities, materials, services and personnel to design, fabricate, assemble and test the necessary electrical, optical and mechanical GSE to support the:

1) Spacecraft component and subsystem development;

2) assembly, alignment, test and verification of the Spacecraft; and,

handling and integration of the Spacecrafts with the GRACE Instruments into the GRACE Satellites.

4.4.3 Instruments

UTCSR, together with JPL and the GRACE Mission Team shall provide the facilities, parts, materials, services and personnel to design, fabricate, assemble, test and deliver for integration with the Spacecrafts, two spaceflight qualified Instruments for the GRACE Mission. These efforts shall include, but are not limited to, performing the necessary analyses to ensure functional requirements are met, and preparing design drawings and data packages. UTCSR and the GRACE Mission Team shall also develop any test equipment necessary to test GRACE instruments. UTCSR and the GRACE Mission Team shall also provide the facilities, materials, services and personnel to design, fabricate, assemble and test the necessary electrical, optical and mechanical GSE to support the:

1) Instrument component, subsystem and system development;

2) assembly, alignment, test and verification of the Instrument; and,

3) handling and integration of the Instruments with the GRACE Spacecrafts into the GRACE Satellites.

4.5 LAUNCH VEHICLE INTERFACE REQUIREMENTS

UTCSR, together with JPL and the GRACE Mission Team shall provide the necessary GRACE Satellite information and data to the launch services contractor to develop an interface control document (ICD) between the launch vehicle and the GRACE Satellites. This shall include the delivery of any necessary drawings or analytical models. UTCSR shall approve the ICD and be responsible for verifying compliance of the Satellite interfaces to the specifications in the ICD.

4.6 GROUND SYSTEM DEVELOPMENT

UTCSR, together with JPL and the GRACE Mission Team shall provide the facilities, equipment, services and personnel to design, develop and validate a ground system which shall be capable of supporting the GRACE Mission Operations for a period of five (5) years under this contract. The ground system shall be comprised of the:

1) the German Space Operations Center (GSOC) which is the central node of the ground system from which all mission operations and data handling functions will be conducted, and from which the science data is distributed to JPL and GFZ for subsequent distribution of processed data.

2) ground station(s) which provides the uplink and downlink between the Satellites and the ground system; and

3) communications link between the GSOC and the ground station(s).

UTCSR, together with JPL and the GRACE Mission Team shall be responsible for the development, validation and verification of the GRACE Satellite flight operations software which will provide the processes for:

1) commanding the Instruments and Spacecrafts;

2) collecting, handling, formatting and processing the science and engineering data;

3) monitoring the Satellite health and safety;

4) communications link between the GSOC and JPL

UTCSR together with JPL and the GRACE Mission Team, shall manage the development of the GRACE Satellite flight software in accordance with the GRACE Software Development Plan.

UTCSR along with NASA provided mission operations team, JPL and the GRACE Mission Team, shall select and train the members of the Mission Operations Team (MOT) who will be responsible for the flight operations.

UTCSR, together with JPL, shall define the requirements and develop a system for the acquisition, processing, and distribution of the GRACE science data. JPL shall prepare the Mission Operations and Data Management Plan which describes these requirements and the system design. UTCSR and the GRACE Mission Team shall provide the facilities, equipment, services and personnel necessary to implement the GRACE Mission on-orbit according to the provisions of the plan.

To reduce the risk of deliberate or accidental corruption or loss of the GRACE science data, the GRACE Mission Team shall implement security and backup procedures.

The GSOC shall be capable of transferring the processed science data to the designated U.S. archive facility, as soon as it has been validated. Deliverable science data sets and their delivery schedule shall be consistent with the requirements of the GRACE Mission Definition and Requirements Agreement [Contract Attachment D] and the GRACE Science and Mission Requirements Document [Contract Attachment E].

UTCSR, together with JPL and the GRACE Mission Team shall develop a configuration of subsystem engineering test units (ETUs) and GSE appropriate for the maintenance of the flight software and for supporting trouble-shooting of the satellites while in orbit.

4.7 SATELLITE OPERATIONS

UTCSR , together with JPL, the DLR and the GFZ, shall provide the personnel to support the mission pre-launch and launch activities, the on-orbit checkout of the Satellites for 30 days after launch, and the flight operations of the Satellites for 5 years thereafter. These activities will take place both at the launch site and the GSOC.

4.8 DATA ACQUISITION, PROCESSING AND DISTRIBUTION

UTCSR, together with JPL, the DLR and the GFZ shall provide the facilities, equipment, services and personnel necessary to acquire, process and distribute GRACE science data and science data products. UTCSR shall be responsible for transferring the processed science data to the PODAAC, or an equivalent Government archive facility, as soon as it has been validated. Deliverable science data sets and their delivery schedule shall be consistent with the requirements of the GRACE Mission Definition and Requirements Agreement [Contract Attachment D] and the GRACE Science and Mission Requirements Document [Contract Attachment E].

4.9 EDUCATIONAL AND PUBLIC OUTREACH OPPORTUNITIES

UTCSR shall develop and implement a comprehensive plan for providing educational and public outreach opportunities within the GRACE Mission, documented in the Education and Public Outreach Plan [Contract Attachment F].